TECHNICAL MEMORANDUM

Date: July 7, 2003

Prepared For: Kevin O'Neill/DOE-ID

Prepared By: Thomas Borschel/BBWI
Melvin Main/Main Associates
Craig Bean/BBWI

CC: Doug Jorgensen/BBWI
Mike Edgett/BBWI
Pam French/BBWI
Pat Gibson/BBWI
Jodi Landis/BBWI

Subject: **INEEL CERCLA DISPOSAL FACILITY WASTE PLACEMENT COMPACTION DEMONSTRATION**

Introduction and Objective

The U.S. Department of Energy (DOE) authorized a remedial design/remedial action for the Idaho National Engineering and Environmental Laboratory (INEEL), including the Idaho Nuclear Technology and Engineering Center (INTEC), in accordance with the Waste Area Group (WAG) 3 Operable Unit (OU) 3-13 Record of Decision (ROD). The ROD requires contaminated surface soils to be removed and disposed of on-Site in the INEEL Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Disposal Facility (ICDF).

Associated with the aforementioned landfill disposal operations is the need to compact and verify that placed waste soils meet the requirements to minimize future subsidence. This technical memorandum provides the results of a field test that used two methods to initially correlate equipment passes with density/subgrade reaction for specific, anticipated soil types.

The effort's purpose was to collect information and establish a process for compacting waste soil into the ICDF Landfill. As the soils are remediated from the different WAGs, they will be transported to and prepared for placement into the landfill. The placement and compaction of the soil is critical to maintaining required soil volume reduction and stability of the eventual landfill cap when the cell structure has been filled. To ensure protection of human health and the environment, it is critical that the future landfill cap does not subside or crack. The compacted fill is the foundation for placement of the final cap.

During the field test, representative soil types were acquired, characterized, and compacted using the actual equipment destined for landfill operations. The first step was to develop a correlation between soil types, dozer passes, and the resulting density, as compared to required traditional performance standards. Following this step, a comparison between standard nuclear density gauge measurements versus direct subgrade reaction measurements by a Humboldt GeoGauge was conducted to evaluate the potential for an alternate method for field verification of waste soil compaction. This technical memorandum describes the process employed in the demonstration, and presents the results and recommendations.

Representative Soil Type Selection

As described in the ICDF Remedial Design Construction Work Plan (RD/CWP) (DOE-ID 10848), DOE agreed to test the three prominent soil types expected to be encountered at the various WAGs. Three types of soil were selected for construction of a test strip that best represented the initial anticipated contaminated waste soils types destined for the ICDF. Included was a sandy gravel mix representing the majority of soils coming from WAG 3, within INTEC. A lean clay from the Rye Grass borrow source was selected to represent those remediation sites that would have the finest grain sizes. Readily available surface soil from the Central Facilities Area (CFA) was substituted for soil from the Auxilary Reactor Area (ARA) WAG 4 sites, due to availability of that material; the CFA material was determined to be equivalent, as demonstrated by the similarity of index test results performed on samples from ARA. The soil types used for the test strip are shown in Table 1 and are noted in bold.

Soil Index Testing

To confirm that the candidate soil types were representative of the proposed remediation areas, index testing was performed at the INEEL Material Testing Laboratory. The maximum dry density and corresponding optimum moisture content was determined by using test method ASTM D698 (Standard Proctor Method). Additionally, the grain size distribution was determined by sieve analysis. Results are presented in Table 1. Comparison plots of particle size distribution, compaction test reports, and Atterberg limits are all presented in Appendix C.

Evaluation of Soil Compaction

A test strip was constructed with the candidate soil types in the confines of the permanent stockpile, located south of the ICDF Landfill. Plots measuring 25 ft × 25 ft were prepared with each of the three soil types to form a test strip 75 ft in length. The ICDF D9 Cat was mobilized and the test equipment, the Troxler Nuclear Gauge (traditional) and Humboldt GeoGauge (proposed new gauge), were staged. The detailed test report is presented in Appendix A. Digital photographs were taken during the test strip compaction and subgrade reaction measurements and are contained in Appendix B.

Table 1. Soil index testing results.

	Pit Run Gravel/Sand (GW)	**CFA Overburden (CL-ML)**	ARA Surface Soil (ML)	**Rye Grass Flats (CL)**
Maximum Dry Density (PCF)	**139.7**	**105.5**	103.9	**106.6**
Optimum Moisture (%)	**5.9**	**16.1**	16.6	**18.6**
Liquid Limit (%)	**N/A**	**24.7**	23.8	**35.8**
Plasticity Index (%)	**N/A**	**5.1**	1.8	**17.1**
% Gravel	**59.8**	**5.4**	5.3	**0.0**
% Sand	**36.7**	**25.8**	27.0	**10.6**
% Fines <#200 Sieve	**3.5**	**68.8**	67.7	**89.4**

Conclusions and Recommendations

This waste placement compaction demonstration provided a good first step towards the correlation of D9 Cat dozer passes versus soil types. Additionally, it demonstrated the viability of using a subgrade reaction measurement by the Humboldt GeoGauge to augment and ultimately replace the standard nuclear gauge measurement to verify compaction of earthen materials.

The success of the subgrade reaction method is contingent upon proper lift thickness, moisture conditioning, and application of compactive effort, all of which are carefully defined in the waste placement procedures.

It is recommended that two Humboldt GeoGauges be procured. It is suggested that one gauge be assigned to the CFA Materials Testing Laboratory quality inspection staff (to support ICDF compaction quality assurance verification), and that the other gauge be provided as government-furnished equipment to the ICDF operations subcontractor for waste placement quality control. In addition, it is recommended that the quality inspection staff and subcontractor continue the use of both gauges initially, to add to the body of comparison data and better define the appropriate target stiffness required.

Upon gaining a statistically justifiable correlation based on a larger data set per soil type, the Humboldt GeoGauge can then be implemented as the sole method to verify that waste placement criteria has been met in the radiological environment.

Appendix A

Test Report:
Evaluating Soil Compaction Utilizing the Humboldt GeoGauge

March 31, 2003

Prepared for:
Idaho National Environmental & Engineering Laboratory
CFA 602
Scoville, ID 83415

Prepared by:
Humboldt Mfg. Co.
7300 West Agatite
Norridge, IL 60706

Appendix A

Test Report: Evaluating Soil Compaction Utilizing the Humboldt GeoGauge

On March 25th and 26th, 2003, testing was conducted at the Idaho National Environmental and Engineering Laboratory (INEEL) to determine if GeoGauge measurements could serve as an in-place index of conventional levels of compaction on soils contaminated with nuclear waste. The goal is to be able to assign a range of stiffness at a moisture content that will correspond to a standard Proctor 90% compaction for each material.

On March 25th, three uncontaminated, representative materials were placed as illustrated in Figure 1. The representative materials were sandy gravel with fist-size cobbles, silty topsoil, and lean clay. All were placed in a single 2-ft lift, near optimum moisture content, with as little effort as possible. A Caterpillar D9 bulldozer was used to compact the soil via "track walking," since this equipment will be used to place and compact contaminated soil in INEEL's waste disposal sites. A pass of the D9 Cat was defined as 100% track coverage in one direction. Density and moisture via a nuclear gauge, and stiffness via the GeoGauge were measured in the configuration illustrated in Figure 1 on passes 0, 1, 2, 4 and 6. Test locations were prepared by scraping and flattening with the nuclear gauge's scraper plate. Moist sand was used in all cases to assist the seating of the GeoGauge. The Toxler and Humboldt readings were each averaged for all the test locations within each soil type section, for each D9 roller pass number. The results are summarized in Figures 2, 3, and 4.

In general, density and stiffness track each other on March 25th, as a function of effort for the silty topsoil and the lean clay. This made assigning a target stiffness at moisture content to 90% compaction possible. This was not true initially for the sandy gravel. During soil compaction, both density and stiffness at a relatively constant moisture content should increase steadily to a maximum, and then decrease with accumulative compactive effort. This is not shown in the data. The nature of both density and stiffness was to oscillate with accumulative effort. The lift thickness was approximately twice that expected in practice. The moisture content varied about 8 times more than expected as a function of effort. All of these facts lead to the conclusion that the soils, as placed, were very non-uniform in both composition and moisture content, and that the soil was being kneaded as much as compacted by the application of effort. Since the soil placement and composition was believed not to be representative of practice, a decision was made to replace and retest the sandy gravel on March 26th.

On March 26th, using the D9 Cat, approximately half the sandy gravel was graded away and the remainder thoroughly compacted with passes in multiple directions until 90% compaction or greater was achieved, simulating a previous passing lift. The remaining 1 ft of material was graded back into position, while being mixed thoroughly and compacted minimally. The material appeared to be uniformly graded and of a dark, uniform color. This was not the case, however, on March 25th. On the 25th, the number of test locations was increased and the proximity of density and stiffness measurements were decreased, as illustrated in Figure 1.

Prior to measurements, test locations were prepared by removing the top 3 ft to 6 ft of soil that was loosened by the D9 track, and surface voids were filled with sieved local fines. This was not done on March 25th.

Density and moisture via a nuclear gauge and stiffness via the GeoGauge were measured in the configuration illustrated in Figure 1 on passes 0, 1, 2, 4, and 6. The results again were averaged across all test locations, for the specific soil section and each D9 pass. The results are summarized in Figure 5. The results were as expected, showing both density and stiffness at a relatively constant moisture content, steadily increasing to a maximum and then decreasing with accumulative compactive effort. These results indicated that assigning a target stiffness at moisture content to 90% compaction is not only possible, but practical as well.

The GeoGauge and associated supplies were retained by INEEL, on loan from Humboldt for a month, with the intent to supplement the results with additional tests.

The INEEL intends to recommend this method to DOE-ID, EPA, and IDEQ as an option for compaction QC/QA of waste placement in the ICDF, to minimize worker exposure and reduce interference of contamination with standard nuclear source density measurements.

At this point, recommending a final target stiffness representing 90% compaction for the materials in question is difficult, due to the condition and configuration of the materials in our test. Similar to the testing performed on March 26th, if the materials are mixed somewhat uniformly and placed in 10 ft to 12 ft lifts, compaction will behave more predictably and stiffness will be 30 to 50% higher than what was measured on March 25th. Therefore, the silty topsoil and lean clay will require retesting, as we performed on the sandy gravel to establish meaningful preliminary targets. A final target stiffness can be established when values remain statistically unchanged after several test strips are evaluated. As for the sandy gravel, 90% compaction seems to be reached just by placing the material. A higher level of compaction may need to be specified to assure uniformity of placement and performance. For example, the March 26th data suggests that a 93% threshold may be appropriate, which corresponds to > 125 pcf and > 9.3 MN/m at 5% moisture content. This preliminary target is valid if the moisture content of the tested material is close enough to the optimum of ~ 7%.

Our testing conducted on March 25th and 26th showed that stiffness-based compaction QC/QA is viable. Two or three days of testing controlled and performed on several test strips, like that of March 26th, or parallel testing during waste placement during initial operations, will be sufficient to establish the target stiffness required.

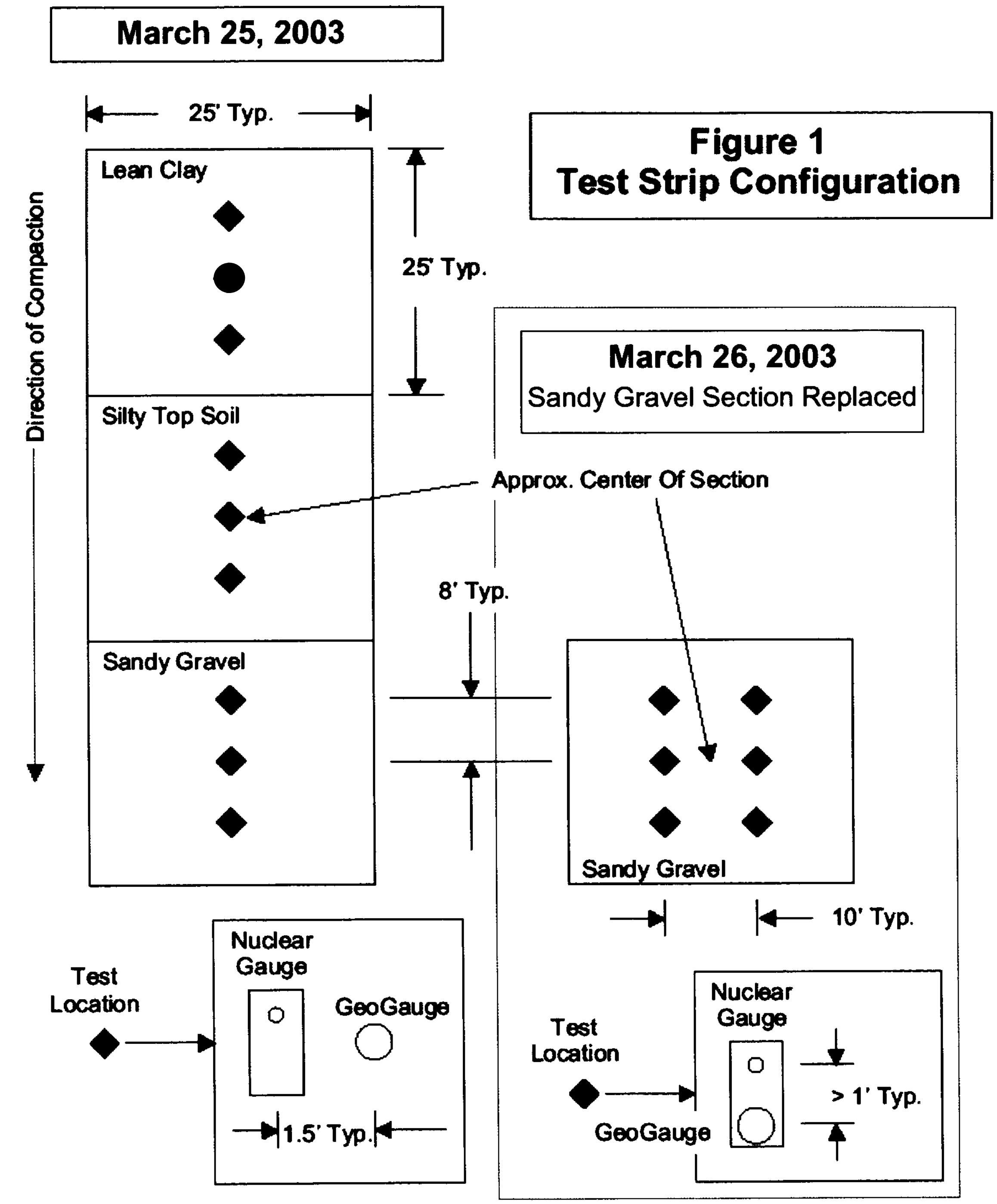
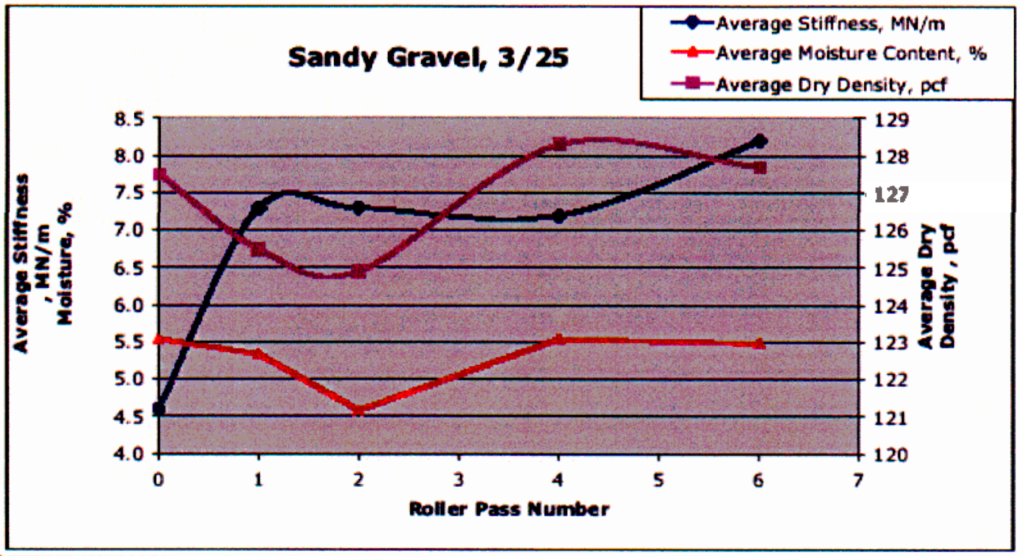
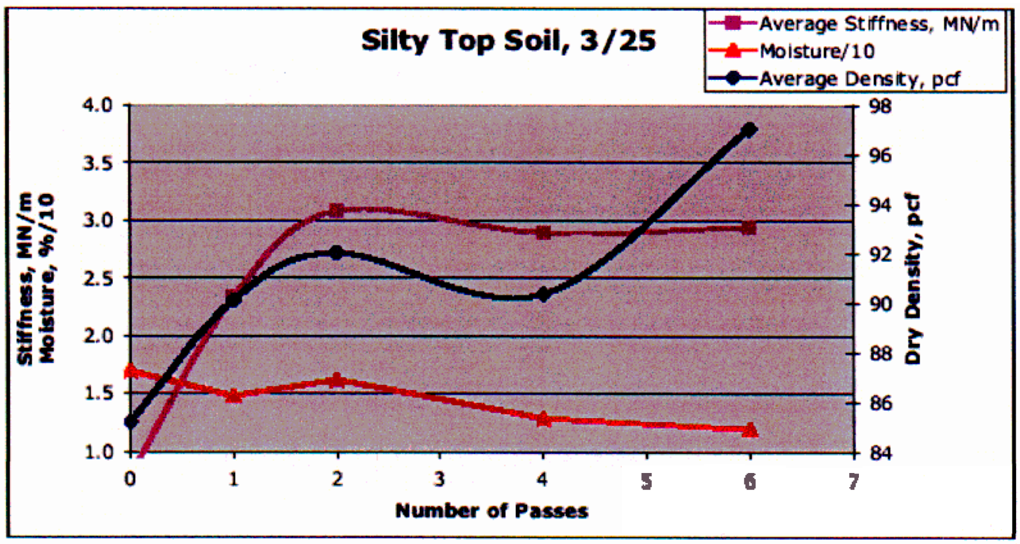

March 25, 2003
25' Typ.
Figure 1
Test Strip Configuration
Lean Clay
25' Typ.
Direction of Compaction
March 26, 2003
Sandy Gravel Section Replaced
Silty Top Soil
Approx. Center Of Section
8' Typ.
Sandy Gravel
Sandy Gravel
10' Typ.
Test
Location
Nuclear
Gauge
GeoGauge
1.5' Typ.
Test
Location
Nuclear
Gauge
> 1' Typ.
GeoGauge

Figure 2



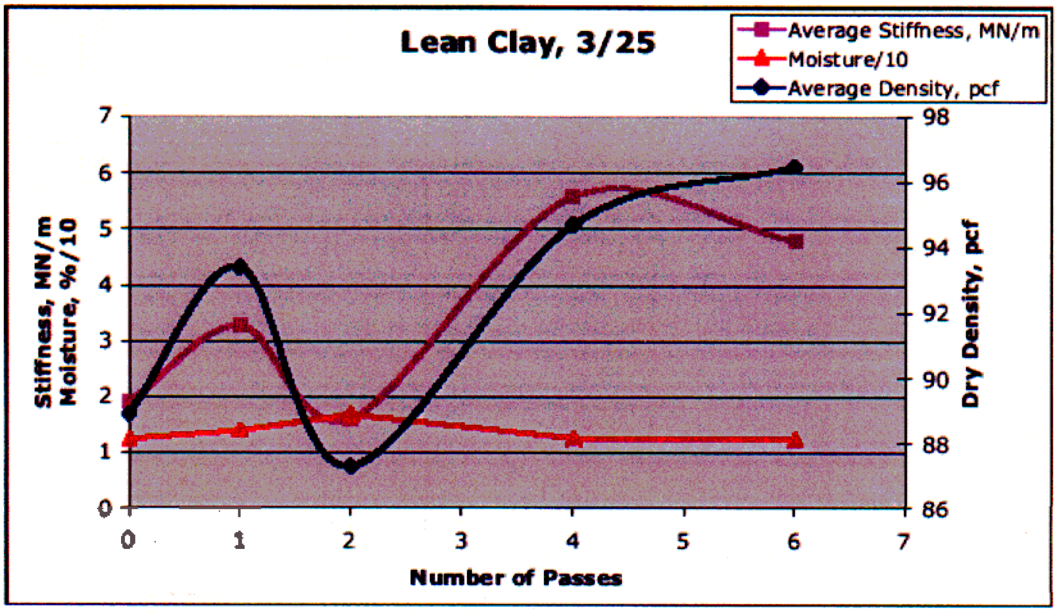
Pass	0	1	2	4	6
Average Density, pcf	127.50	125.50	124.90	128.30	127.70
Average Stiffness, MN/m	4.60	7.30	7.30	7.20	8.20
Average Moisture Content, %	5.53	5.33	4.57	5.53	5.47

Figure 3



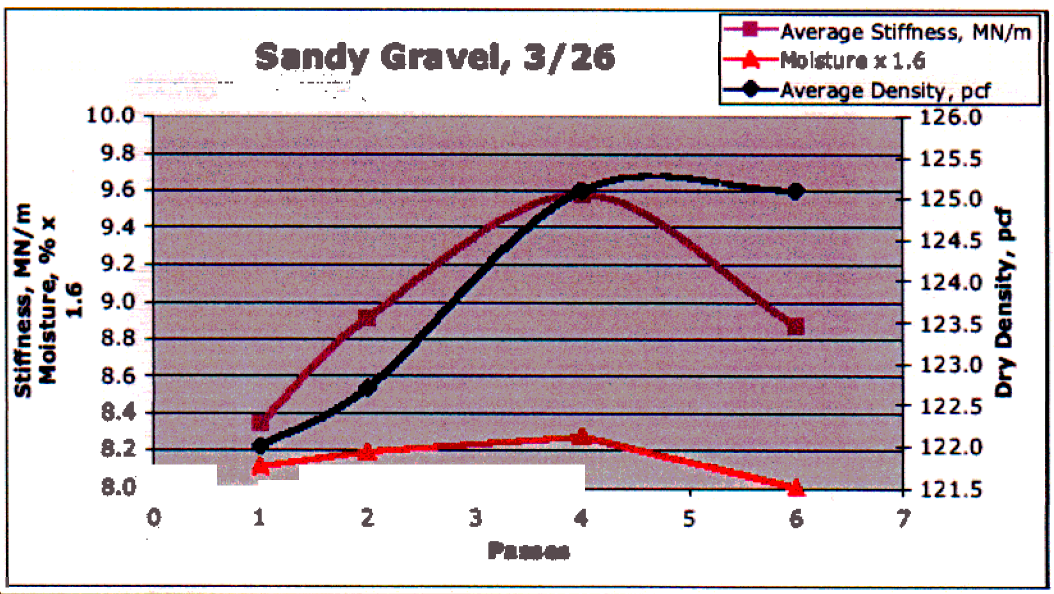
Pass	0	1	2	4	6
Average Density, pcf	85.20	90.10	92.00	90.34	97.05
Average Stiffness, MN/m	0.80	2.33	3.08	2.89	2.94
Average Moisture Content, %	16.95	14.80	16.20	12.85	11.90
Moisture/10	1.70	1.48	1.62	1.29	1.19

Figure 4



Pass	0	1	2	4	6
Average Density, pcf	88.900	93.400	87.300	94.700	96.500
Average Stiffness, MN/m	1.90	3.27	1.60	5.58	4.78
Average Moisture Content, %	12.40	13.90	16.80	12.50	12.40
Moisture/10	1.24	1.39	1.68	1.25	1.24

Figure 5



Pass	1	2	4	6
Average Density, pcf	122.00	122.70	125.10	125.10
Average Stiffness, MN/m	8.34	8.91	9.58	8.87
Average Moisture Content, %	5.07	5.12	5.17	5
Moisture x 1.6	8.11	8.19	8.27	8.00

Appendix B

Photographs

Humboldt GeoGauge vs. Troxler Nuke Density Gauge

D9 Cat to be used for waste placement in ICDF

Offset track walking of test strip with D9 Cat

Side by side testing of Troxler and Humboldt GeoGauge

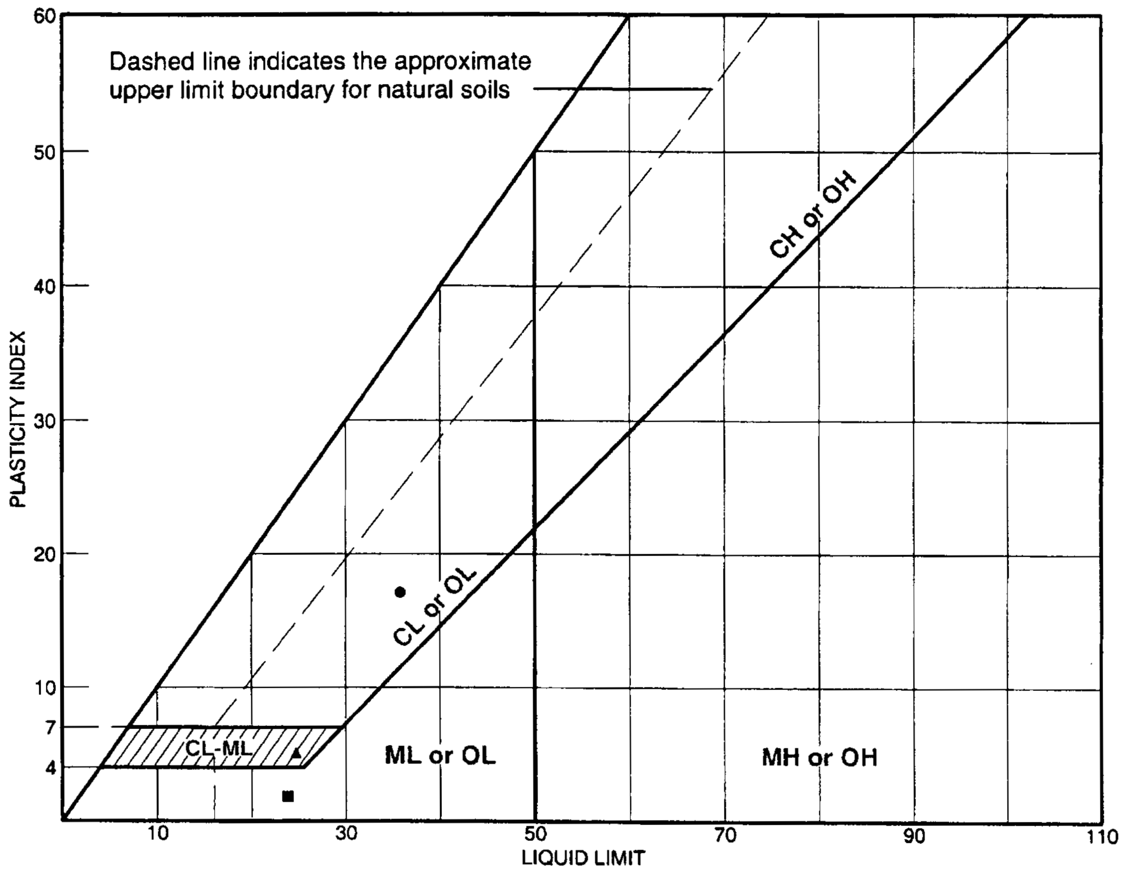
Another series of measurements following D9 Pass

Side view of test strip with three side-by-side soil types

Appendix C

Soil Index Comparison Data

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH (ft.)	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●	Test Pad #2	BBWI-TP2-	West Middle	16.27%	18.7	35.8	17.1	CL
■	ARA (WAG)	ARA WAG	0' - 1.0'	7.9%	22.0	23.8	1.8	ML
▲	CFA Landfill	CFA #1	Bag	None Taken	19.6	24.7	5.1	CL-ML

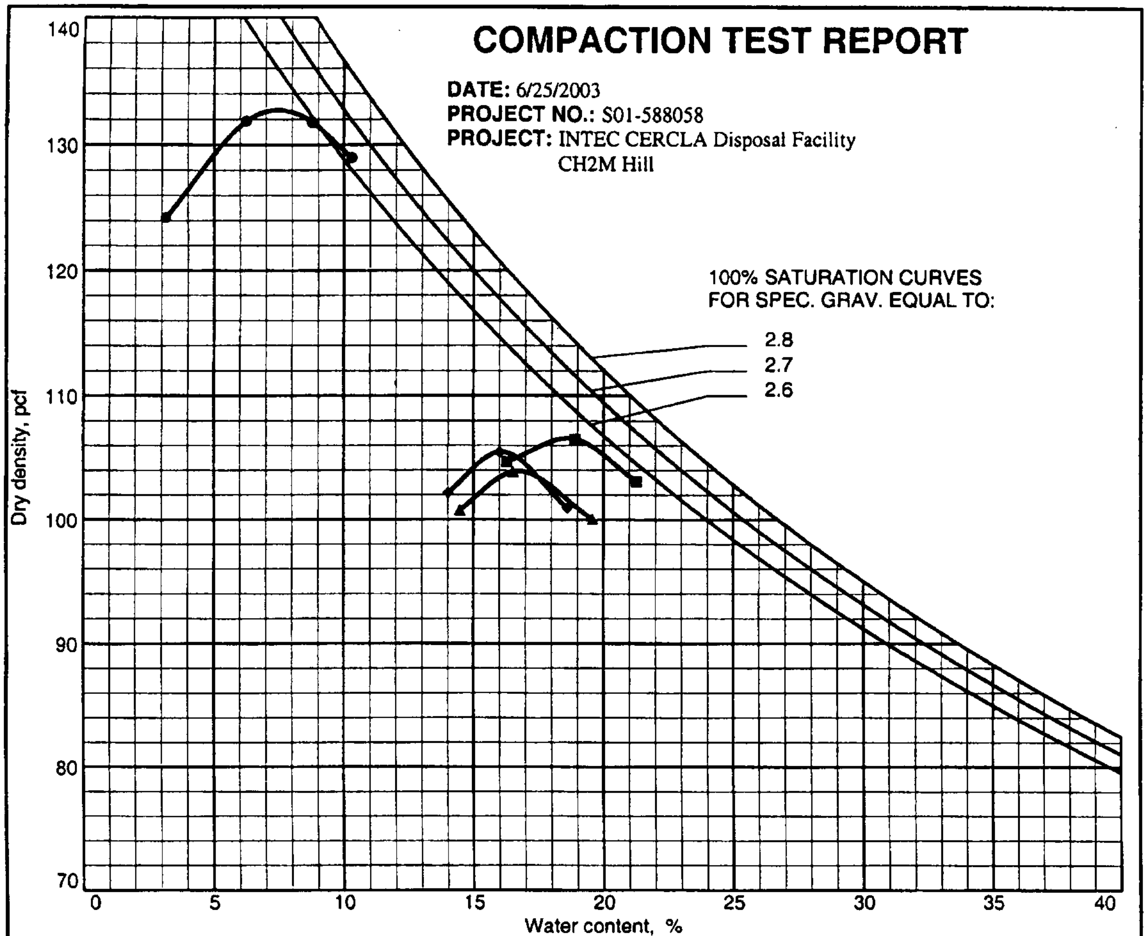
LIQUID AND PLASTIC LIMITS TEST REPORT

INEEL MATERIALS LAB

Client: Tom Borschel/ICDF Project
Project: INTEC CERCLA Disposal Facility
CH2M Hill
Project No.: S01-588058 **Plate**

COMPACTION TEST REPORT

DATE: 6/25/2003
PROJECT NO.: S01-588058
PROJECT: INTEC CERCLA Disposal Facility
CH2M Hill

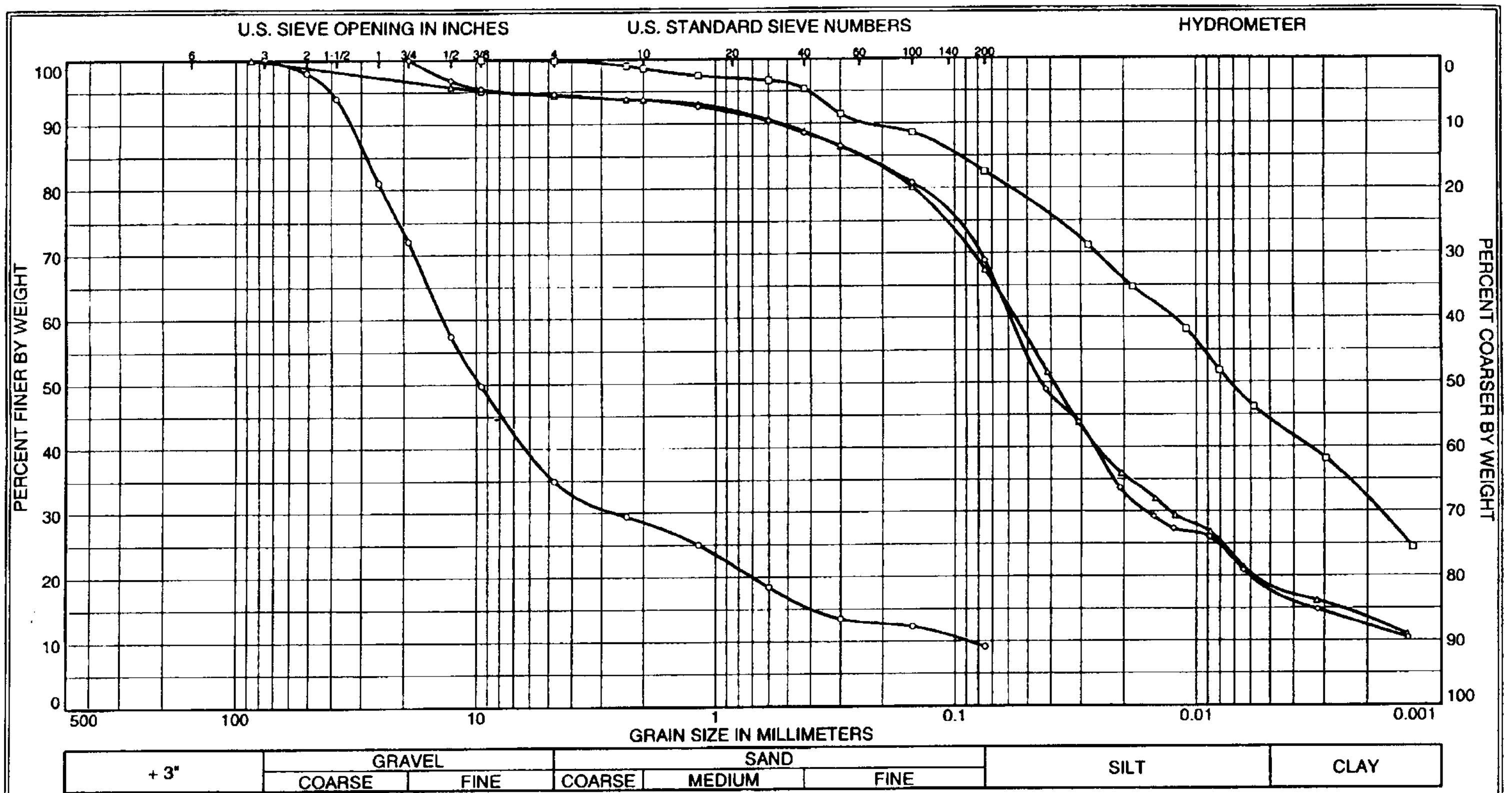


	No.	LOCATION AND DESCRIPTION	TEST SPECIFICATION
●		**Location:** SG #21 excavated from Cell #1 Poorly graded gravel with silt and sand	ASTM D 698-91 Method C Standard
■	Lab #025	**Location:** West Middle of Mix Table, Batch #1 Lean clay with sand	ASTM D 698-91 Method A Standard
▲	Lab Log #10	**Source:** ARA (WAG) **Sample No.:** ARA **Elev./Depth:** 0' - 1.0' Sandy silt	ASTM D 698-91 Procedure A Standard
◆	LabLog #016	**Source:** CFA Landfill **Sample No.:** CFA #1 **Elev./Depth:** Bag Sandy silty clay	ASTM D 698-00a Method A Standard

	No.	USCS	LL	PI	NAT. MOIST.	OVERSIZE	%< No.200	MAX. DRY DEN.	OPT. MOIST.
●		GP-GM	NV		NA	%>3/4 in.=28.0	9.1 %	139.7 pcf	5.4 %
■	Lab #025	CL	35.8	17.1	16.27%	%>No.4=0.2	82.5 %	106.6 pcf	18.6 %
▲	Lab Log #10	ML	23.8	1.8	7.9%	%>No.4=5.6	67.4 %	103.9 pcf	16.7 %
◆	LabLog #016	CL-ML	24.7	5.1	None Taken	%>No.4=5.4	68.8 %	105.5 pcf	16.1 %

Plate

INEEL MATERIALS LAB



	LOCATION	SOURCE	SAMPLE #	DEPTH/ELEV.	MATERIAL DESCRIPTION
○	SG #21 excavated from Cell #1	Cell #1 FootPrint	SG #21	Excavation	Poorly graded gravel with silt and sand
□	West Middle of Mix Table, Batch #1	Test Pad #2 BCL	BBWI-TP2-	West Middle	Lean clay with sand
	West Middle of Mix Table, Batch #1		BCL-02		
△		ARA (WAG) soils	ARA WAG	0' - 1.0'	Sandy silt
			Sample #1		

Project No. S01-588058 **Client** Tom Borschel/ICDF Project **Plate**

PARTICLE SIZE DISTRIBUTION TEST REPORT

INTEC CERCLA Disposal Facility

INEEL MATERIALS LAB